FISH MANAGEMENT REPORT 125
October 1985

PIKES CREEK/LAKE SUPERIOR STEELHEAD POPULATION: POPULATION DYNAMICS, FISHERY, AND MANAGEMENT ALTERNATIVES

By
Bruce L. Swanson, Bayfield

Bureau of Fish Management • Wisconsin Department of Natural Resources, Madison, Wisconsin

ABSTRACT

From 1977-81, the population dynamics of the steelhead (Salmo gairdneri) population in Pikes Creek, Wisconsin were determined through a tagging study, scale analysis, and creel census on this small Lake Superior tributary. This natural steelhead population has demonstrated a strong homing instinct back to Pikes Creek upon maturing in Lake Superior. The 1977-81 annual spawning population was 989 fish, of which 618 were first-time spawners. During this time, approximately 1.4 million eggs were deposited annually, and 0.043% of these survived to become spawners. Once mature, nearly all steelhead spawned annually.

Annual fishing mortality rates (u) were 23.0% for females and 20.0% for males. Annual natural mortality rates (v) for various spawning ages ranged from 54.0% for age IV to 100% for age VIII males, and 33.3% for age VI to 100% for age IX females. Changes in the population structure were estimated for various fishing mortality rates. Impact of regulation changes were reviewed, particularly in regard to maintaining a trophy fishery. The annual fishing mortality rate could be inexpensively monitored using the percentage of repeat female spawners as an index. An annual fishing mortality rate of 20% is recommended to maintain a quality fishery.

TABLE OF CONTENTS

INTRODUCTION

Fishing the steelhead (Salmo gairdneri) anadromous spawning runs in tributaries of the Great Lakes is considered one of the choice fresh water fishing experiences in North America. Wisconsin has only eight steelhead streams with significant natural runs, and they are all tributaries of Lake Superior. The eight streams are the Brule, Cranberry, Flag, Onion and Sioux rivers and Fish, Pikes and Whittlesey creeks (Fig. 1). These streams range in median flows of 7 cfs for the Onion River to 150 cfs for the Brule River.

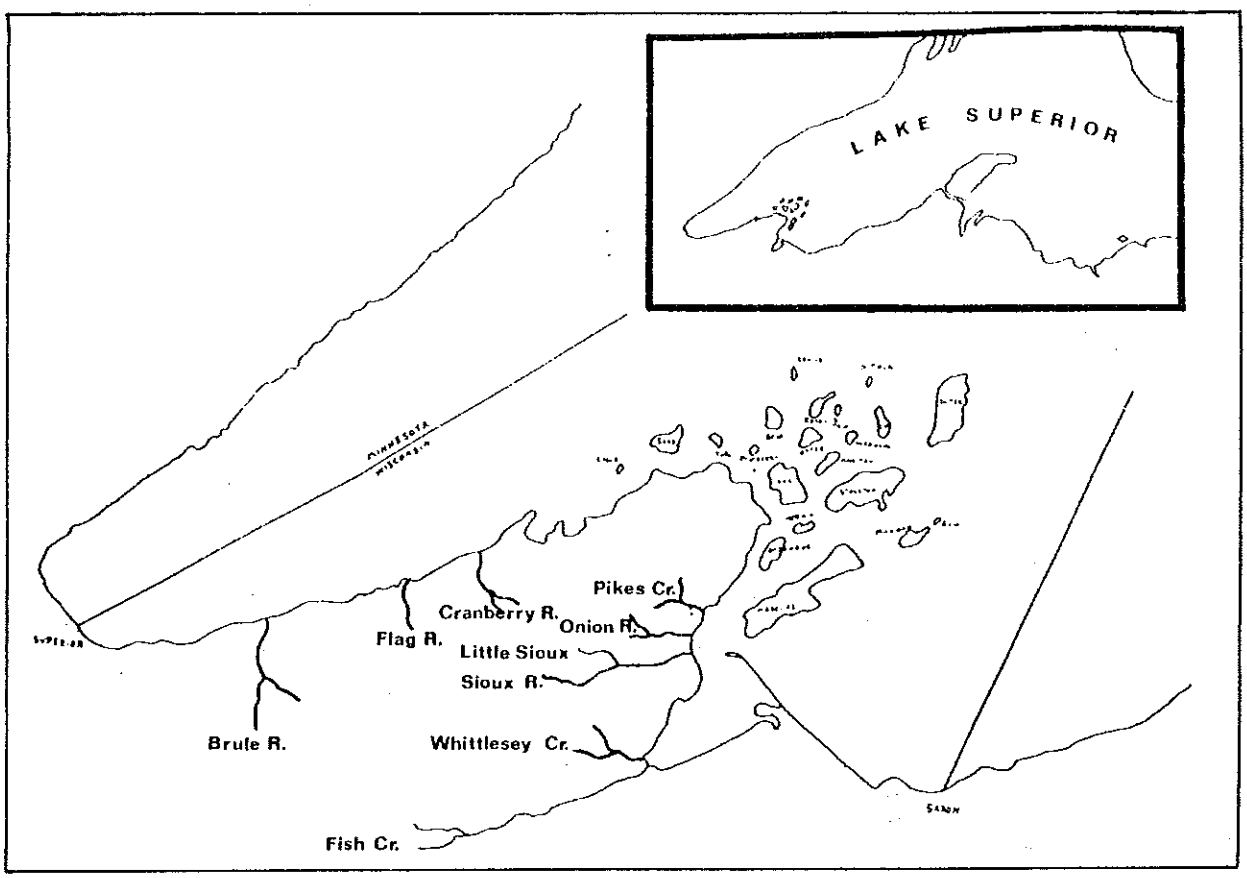


FIGURE 1. Wisconsin streams with significant natural steelhead runs.

Steelhead (rainbow trout) were introduced into Lake Superior in 1895 near Sault Ste. Marie, Ontario (Kwain 1971) and were firmly established by 1905 (MacKay 1963). In the 1950s and early 1960s, lampreys seriously threatened the steelhead runs. With effective lamprey control (from the early 1960s to the present), steelhead rebounded by the mid-1960s to their present levels (Niemuth 1970).

Major obstacles to high quality natural steelhead runs in future decades are habitat deterioration, lamprey outbreaks, species competition, and overfishing. This report will focus on the impact of increasing fishing pressure and efficiency.

Presently, stream fishing pressure on steelhead in the eight streams is a minimum of 39,000 trips annually. This does not include lake fishing pressure. Lake pressure is difficult to determine due to multi-species

targeting, but would probably increase total steelhead fishing trips to 41,000-44,000. Estimated stream fishing pressure for each creek is listed in Table 1.

TABLE 1. Annual number of fishing trips on Lake Superior anadromous steelhead streams, 1974-81.

Stream	No. Trips
Brule River	25,807*
Cranberry River	2,916
Fish Creek	3,718
Flag River	1,240
Onion River	100
Pikes Creek	359
Sioux River	5,060
Whittlesey Creek	100
Total	39,300

*1973-79 only

STUDY AREA

Pikes Creek, located 3 miles south of Bayfield, was chosen as a study stream because of its proximity to the Lake Superior work unit and its small size (150 cfs), resulting in a low cost for continuous spring monitoring. The Pikes Creek watershed is 29.6 square miles, of which nearly all is wooded. Pikes Creek has a methyl purple alkalinity (MPA) of 109 ppm and a specific conductance of 215 µmhos/cm (Johannes et al. 1970). A detailed description of the watershed is given in the 1981 Pikes Creek Stream Survey Report (D. Pratt, Wis. Dep. Nat. Resour. files).

A wooden dam (locally known as Red Dam) was placed on Pikes Creek in the late 1800s to divert water to the Bayfield Hatchery (Fig. 2). In the 1930s, the wooden dam was replaced with an 8-ft concrete dam (from the stream bed to the top) having a sluiceway 3-6 ft high, depending on the number of control boards used. The dam is located 6,380 ft from the lake and most spawning beds are upstream from the dam. A few steelhead jump over the face of the dam during high water conditions, but the bulk of the run passes over the sluiceway.

Steelhead congregate below Red Dam prior to jumping, providing an ideal sampling site for migrating spawners. Very few other anadromous fish, particularly fall-spawning salmon and trout, are able to traverse Red Dam due to low water levels in the fall.

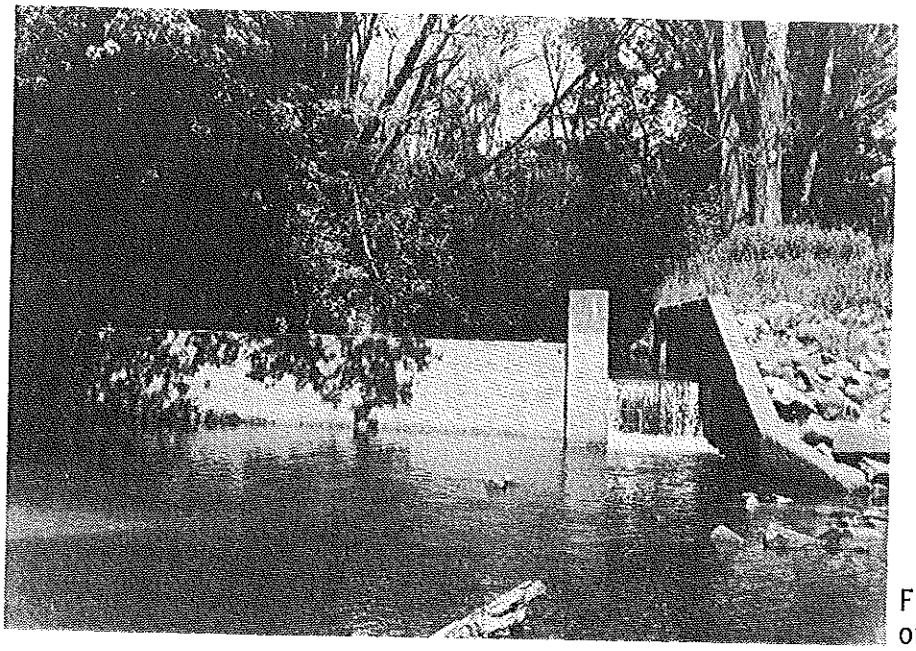


FIGURE 2. The Red Dam located on Pikes Creek, Bayfield County.

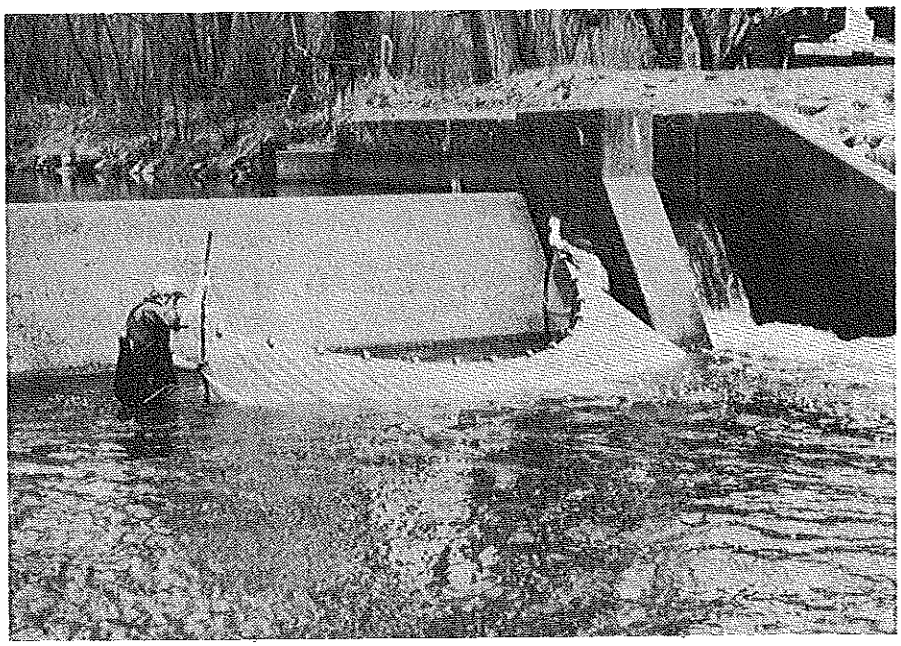
METHODS AND MATERIALS

The study was conducted from 1977-81, using a 25-ft seine (3/4-inch stretch mesh) to sample the steelhead congregated in the pool below the Red Dam. Field records indicate that few steelhead jump Red Dam before the water temperature reaches 42 F. Once the water warms to 42 F, much of the daily incoming portion of the run passes over the dam. The pool was sampled approximately 70% of the run days.

Steelhead were double tagged with FD67C and FD67F (flag removed) Floy tags. The FD67C tag contained a return address and identification number, while the FD67F was used to evaluate FD67C tag loss. Tags were inserted next to the dorsal fin (Fig. 3).

A creel census was conducted for 3-4 weeks starting opening day of the season (first Saturday in May) and terminating when the steelhead returned to Lake Superior and the stream fishery ended. The creel census acted as the recapture period of the fish tagged at the Red Dam. The Bailey modification of the Peterson population estimate (Ricker 1975) was used for population estimates. Scale impressions were made on acetate slides and read on an Eberbach scale reader at 100x.

A stream survey of Pikes Creek was conducted during the summers of 1978-79 using a 240-volt AC shocking unit. The left pectoral fin of each sampled fish was clipped for making population estimates of the Pikes Creek trout populations and for identifying fish when they returned on their spawning run.



Steelhead that congregated below the Red Dam were collected in a 25-ft seine.

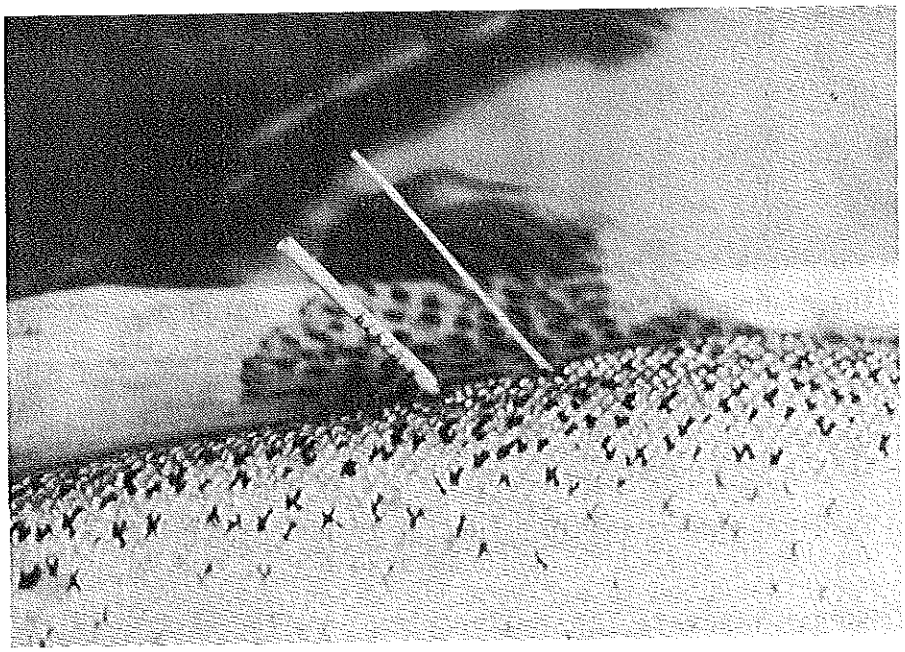


FIGURE 3. A Pikes Creek steelhead with FD67C (left) and FD67F (right, flag removed) Floy tag inserted next to dorsal fin.

RESULTS AND DISCUSSION

POPULATION CHARACTERISTICS

Spawning Period

Steelhead begin to enter Pikes Creek during early April and start passing over the Red Dam about mid-April. Much of the run is normally on the spawning beds by the season opening on the first Saturday in May. The run is usually completed by the end of May.

Size and Age

Female spawners averaged 22.9 inches, ranging from 14.0 to 31.2 inches (total length). Males averaged 18.6 inches, ranging from 10.1 to 29.7 inches (not including a few ripe year-round stream inhabitants). Very few males survived to 25 inches (Table 2).

The mean age of female spawners was 4.96, ranging from III to IX, while males averaged 3.67, ranging from II to VIII. Female and male spawner age structure from 1977-81 is shown in Table 2. Ages IV and V constituted 62.4% of all female spawners, while ages III and IV made up 69.6% of all male spawners.

TABLE 2. Age structure and mean length-at-age for Pikes Creek spawning steelhead, 1977-81.*

Sample Size		Age II	III	IV	V	VI	VII	VIII	IX
				Females					
1,135	Number	--	90	357	351	212	104	19	2
	Percent	--	7.9%	31.5%	30.9%	18.7%	9.2%	1.7%	0.2%
	Length (inches)	--	18.2	22.1	24.0	25.7	26.5	27.5	28.2
				Males					
893	Number	86	383	238	126	44	15	1	--
	Percent	9.6%	42.9%	26.7%	14.1%	4.9%	1.7%	0.1%	--
	Length (inches)	13.0	16.1	20.0	22.5	23.6	25.3	25.3	--

*Units in inches.

Sex Ratio

Females constituted an average of 54.6% of the sampled spawners, ranging from 49.7% (1978) to 65.0% (1981). In the other study years, they were 54.8% (1977), 50.8% (1979), and 52.5% (1980).

In 1981, an early spring thaw and warm weather caused many spawners to ascend the Red Dam during the second week of April. An ensuing cold snap and drop in stream temperature caused many of the females to return downstream to the lake. When the weather (water) began to warm, they re-entered the creek. This resulted in a higher percentage of females in the seining sample than in the actual spawning population.

Spawning Population Estimate

The Pikes Creek spawning population of steelhead averaged 989 fish--with a high of 1,098 in 1981 and a low of 846 in 1980 (Table 3).

Fecundity

Due to lack of extensive steelhead fecundity estimates for Lake Superior, estimates made by Hassinger et al. (1974) and Niemuth (1970) were grouped to produce a fecundity table (Table 4).

Egg Survival

Survival estimates from deposited eggs to the juvenile stage (age I) and then to maturity as first-time spawners were made using the fishing mortality rate (u), population estimate, and creel census information. Approximately 500 females entered Pikes Creek annually, depositing 1.84 million eggs (using previously described fecundity estimates, see Table 4). The sport fishery harvested 115 females annually, of which 75.4% were green and therefore unable to spawn. This dropped the estimate of deposited eggs to 1.43 million.

The survival rate of deposited eggs to age I, 0.79%, was based on the 1978-79 stream survey population estimate of age I in-stream steelhead at 11,060 fish. The survival of age I steelhead to spawning was based on 1977-81 population estimates. The survival of age I females to maiden spawners was 5.0%, while that of earlier maturing males was 5.9%. The combined sex survival was 5.4%. This return of age I steelhead to spawner is similar to the return of fin-clipped steelhead (4.4%).

The survival of eggs to spawner was 0.043% (combined sexes). Assuming fertilized eggs were divided equally for the sexes, the flow chart in Figure 4 shows the number of maiden spawners. An estimated 16.9 acres of Pikes Creek is considered steelhead habitat. With a production of 11,060 yearlings, annual yields of age I steelhead averaged 655/acre. The maiden spawner population consisted of 603 fish or 36/acre.

Age At Emigration

The age when spawners left Pikes Creek as smolts could have been determined using scale readings. An attempt to capture emigrating smolts (to determine the age structure) was made for several years, but flooding or vandalism destroyed the smolt trap. Kwain (1981) found 76% of all emigrating smolts from Stokely Creek were age I, while 23% were age II and 1% were age III. Returning adults, however, showed a different distribution of stream residence as juveniles. Only 41% had spent 1 year in the creek, 53% spent 2 years, and 6% spent 3 years. For returning Pikes Creek adults, age II smolts were the largest percentage for both sexes (Table 5). Adult females appeared to have smolted at a slightly older age (1.62) than males (1.56). No males smolted after age III, while a few females did.

LAKE DISTRIBUTION AND HOMING

Lake Distribution of Spawners

The distribution of lake-harvested steelhead ranged from the mouth of Iron River in Wisconsin to Black River Harbor in Michigan. The average distance traveled from Pikes Creek was 12-13 miles (Figs. 5-A and 5-B). Tag return data (n=36) was strongly related to areas of high fishing pressure, which limits the distribution of returns to areas close to shore. All tag returns were from the sport fishery.

May and June were the months of highest lake harvest (not including late winter ice fishing at Pikes Creek mouth), with a few returns reported in late

TABLE 3. Population estimates of Pikes Creek steelhead spawners, 1977-81.

Year	Population Estimate (± 95% C.I.)
1977	1,050 ± 281
1978	931 ± 194
1979	1,021 ± 222
1980	846 ± 223
1981	1,098 ± 159

TABLE 4. Fecundity of steehead in Lake Superior.*

Age	Avg. Fecundity	Sample Size
III	2,222	3
IV	2,600	5
V	3,602	12
VI	5,542	10
VII	4,985	4
VIII	5,549	2
IX	5,926	1

*Based on estimates by Hassinger et al. (1974) and Niemuth (1970).

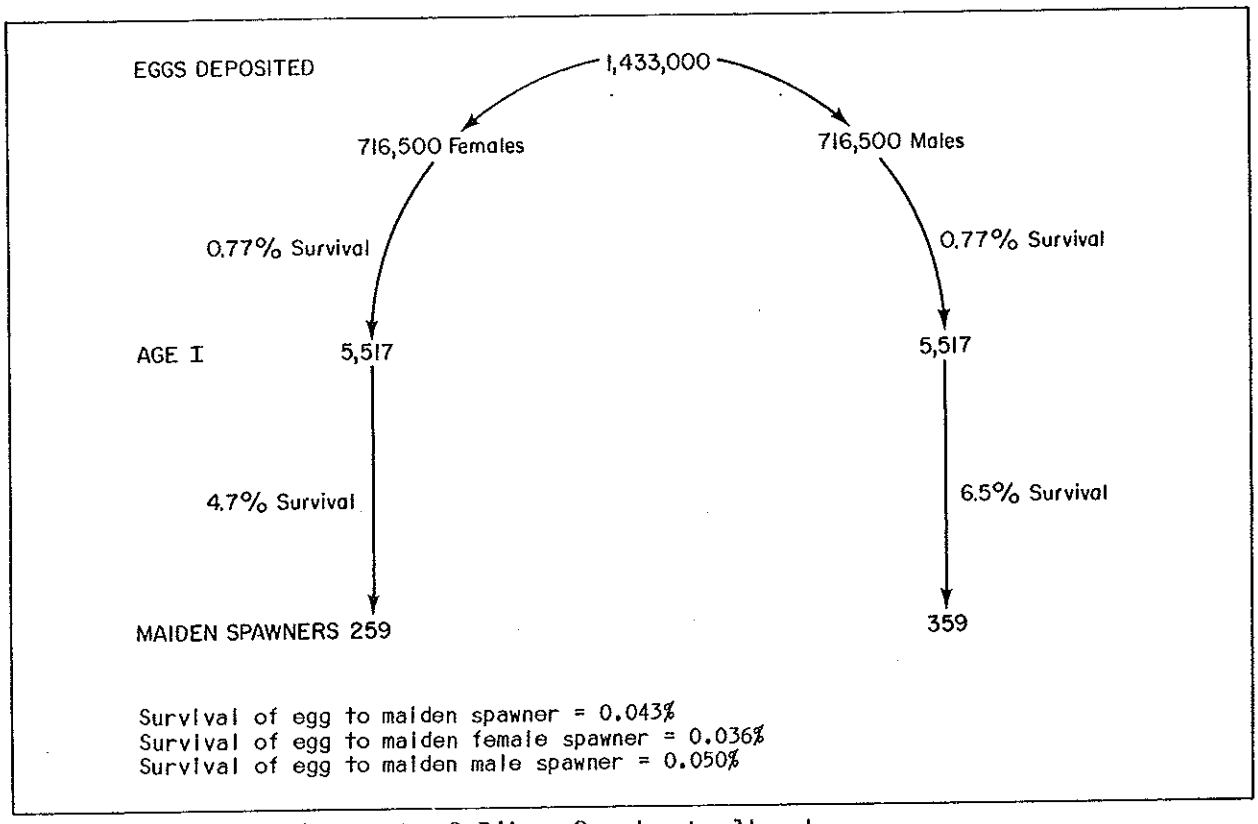


FIGURE 4. Survival chart of Pikes Creek steelhead.

September-October. The harvest in May-June is likely due to the concentration of voracious steelhead leaving the stream into a high fishing pressure area. The lake-harvested steelhead consisted of 81.8% females. This is possibly due to sexual differences in natural mortality rates which is addressed later.

Homing

Of the 1,239 steelhead tagged with numbered Floy tags spawning in Pikes Creek from 1976-80, 134 were recaptured at spawning time. Only 4 wandered to other streams, apparently to spawn, while 130 returned to Pikes Creek. A quantitative estimate of homing vs. wandering is not possible because if a fish entered Pikes Creek and was caught in the sport fishery, it would have a

TABLE 5. Smolting age of mature Pikes Creek steelhead.

	I	II	III	IV	V	Sample Size
Females	42.2%	54.0%	3.2%	0.5%	0.1%	949
Males	45.8%	51.9%	2.3%	--	--	703

high chance of being sampled by the creel census, whereas most streams on Lake Superior are not censused. Four of the five major steelhead streams in Wisconsin were creel censused during the study period--Fish Creek, Flagg, Sioux and Cranberry rivers. The Brule River was censused in 1978-79, and no tagged Pikes Creek steelhead were detected.

If a tagged Pikes Creek fish was caught spawning a year or more after tagging in another creek (other than those mentioned above), the tag would have had to be sent voluntarily by the angler.

Some interesting tag returns warrant mentioning. Of the fish tagged in Pikes Creek that wandered, one was a male tagged in Pikes Creek in 1977 and Michigan. Another was a female tagged in 1979 in Pikes Creek and recaptured 240 miles away in May 1980 at Forest Lake Dam, Au Train River, Michigan. One female tagged in Pikes Creek in 1980 was recaptured by T. Busiahn (Red Cliff Tribal Biologist) in the lower Raspberry River, north of Pikes Creek, on 24 April 1981. It was released and was caught 8 days later by a sport angler in Pikes Creek upstream from the Red Dam.

One female tagged at Red Dam on 19 April 1981 was caught on 30 April 1982 by an angler on the Sioux River, 4 miles from Pikes Creek. Another female tagged in Pikes Creek on 25 April 1978 was caught by a sport angler on 20 May 1978 below the dam on the White River (14 miles from Pikes Creek).

SMOT AND REPEAT SPAWNERS

Return of Smolts To Spawn

During a 1978-79 summer stream survey, 4,112 steelhead were given a left pectoral fin clip. Approximately 1% were young-of-the-year (YOY), 88.4% age I, 9.0% were age II, 1.3% were age III, and 0.2% were age IV. An estimated 4.4% returned to spawn (age III-VIII). This is based on a 43.6% sample of the total run at the dam.

It is interesting to note that 7.1% of the fish with the left pectoral fin clip that returned as spawners had "hump back", or curved peduncles (likely deformed spinal columns). This probably occurred during the electro-shocking survey. In contrast, only 0.5% of the nonclipped population had suspected deformed spines. Some of these steelhead could have been shocked during the survey but avoided capture. Similar spinal deformities have been attributed to the electric lamprey weir on the Brule River steelhead run (DeVore and Eaton 1983).

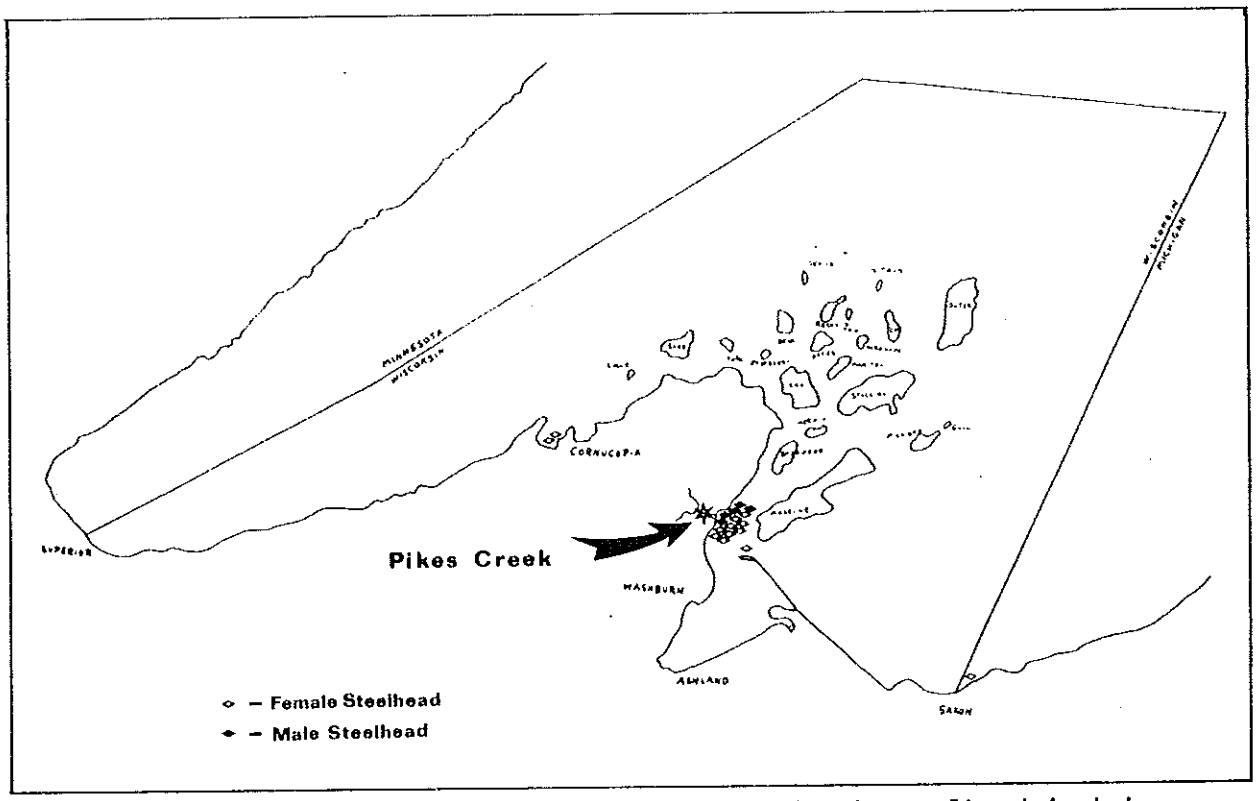


FIGURE 5-A. Location of capture of tagged Pikes Creek steelhead in Lake Superior during February-May, 1977-81.

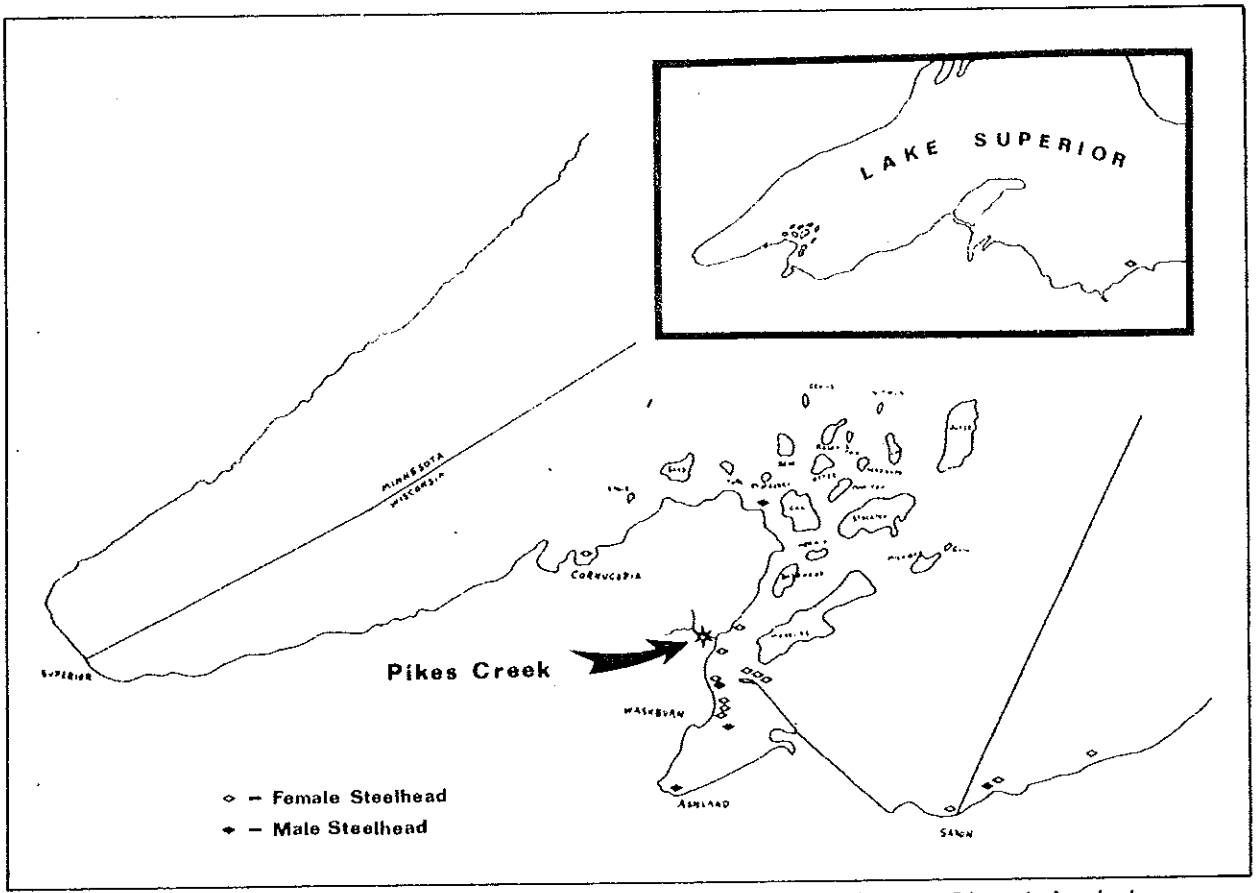
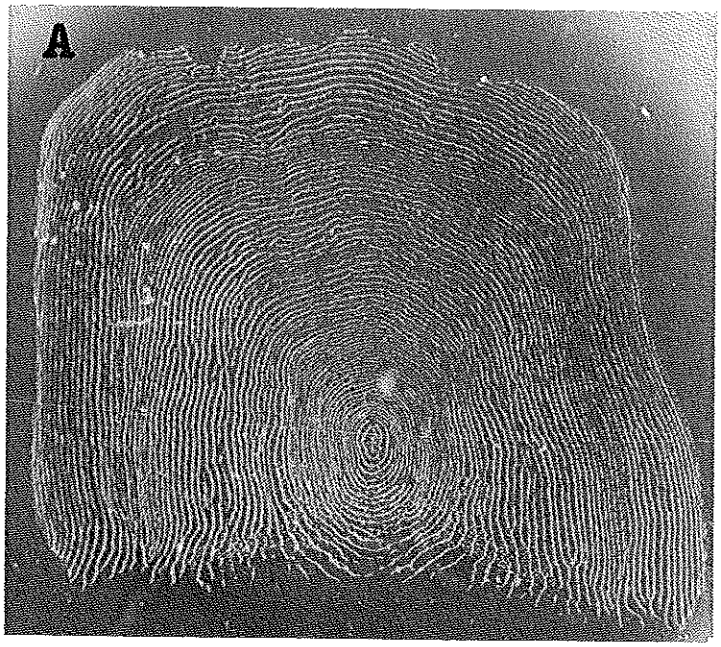


FIGURE 5-B. Location of capture of tagged Pikes Creek steelhead in Lake Superior during June-January, 1976-81.



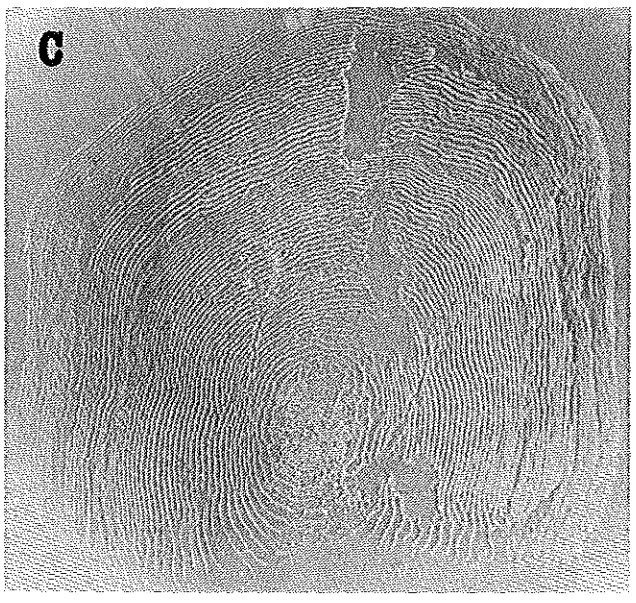


FIGURE 6. Lateral and posterior steelhead scale erosion during previous spawning(s) allows estimates of number of times fish has spawned. Scales were taken during spawning runs. (A) is a maiden spawner (no spawning checks). (B) is a second-time spawner (one spawning check). (C) is a third-time spawner (two spawning checks).

Repeat Spawners

During this study, scale samples from fish that spawned more than one year allowed for a cursory evaluation of the accuracy in determining the number of times a repeat spawner has spawned or number of spawning checks on the scale. Scale erosion in the lateral and posterior scale edges during spawning becomes distinct when new circuli are added to the scale after post-spawning growth begins (Fig. 6).

As the number of spawning times increased, the accuracy decreased. A test of the scale aging techniques revealed that maiden spawners were easily determined, while the accuracy of 2nd and 3rd time spawners was 78.6% and 75.2%, respectively. The accuracy in determining 4th time spawners was very poor at 33.3% (only 3 fish in the sample). (See Table 6).

The age structure in conjunction with percentages of repeat spawners for females and males are shown separately in Table 7. At age IV, 19.3% of the females were repeat spawners, while at age VI, 84% had spawned before, and at age VII and older, all were repeat spawners. Of all male spawners, 38.4% were repeaters at age IV, while 100% were repeaters at age VII.

TABLE 6. Accuracy of scale aging techniques in determining repeat spawners.

	Number of Times Spawning			
	1	2	3	4
Correct Reading	8	11	9	1
Incorrect Reading	0	3	3	2
% Correct	100.0	78.6	75.0	33.3%

TABLE 7. Composition of female and male repeat spawners in Pikes Creek, 1977-81, by age group.

Age	Maiden Spawners	Repeat Spawners	% Repeat Spawners
		Female	
III	66	--	0.0%
IV	284	68	19.3%
V	128	131	50.6%
VI	20	105	84.0%
VII	0	28	100.0%
VIII	0	4	100.0%
		Male	
II	8	0	0.0%
III	164	10	5.7%
IV	45	28	38.4%
V	18	43	70.5%
VI	2	18	90.0%
VII	0	6	100.0%

Male repeat spawners showed up very poorly in tag returns compared to females. Of 669 tagged males, 35 (5.2%) were caught spawning in subsequent years, while of the 800 tagged females, 87 (10.9%) were caught spawning in following years. No males were caught spawning a third time. Scale analysis indicated that most steelhead, once mature, spawn each year thereafter without skipping any years. At most, 1.2% of the males and 1.3% of the females may have skipped a year between spawning. Table 8 summarizes the number of repeat spawners by sex and age.

FISHERY

Stream Fishery

The Pikes Creek steelhead run was intensively fished on the regular season opening weekend, after which pressure began to subside. The season ended in about three weeks. Annual fishing pressure (individual angler trips) over the 5-year period averaged 359 trips, ranging from 320 in 1978 to 476 in 1981 (18.5% nonresidents). The estimated in-stream harvest of steelhead averaged 213 fish, with a low of 105 taken in 1977 and a high of 414 in 1981 (Table 9). Creeled steelhead averaged 23.0 inches for females and 18.5 for males.

The average time it took to harvest one of these trophy fish gives some idea of the effectiveness of the angler (Table 10). In 1977 (poor weather and water conditions), it took 12 hours to harvest a fish, while in 1980 (excellent weather and water conditions), it took only 4.9 hours. The hours fished per steelhead caught for 1977-81 indicates a possible trend to higher angler efficiency. It must be kept in mind that opening weekend weather played a very significant role in the hours per fish and total harvest.

Increased efficiency may translate into more snagging. People familiar with the Pikes Creek fishery say that snagging is a prominent feature of the fishery. Anglers are also using better gear, such as graphite rods.

Fishing Mortality

Using the population estimate and the creel census harvest estimate, annual in-stream fishing mortality rates ($\underline{u}$) were obtained (Table 11). The lowest $\underline{u}$ was 0.13 (1977), while the highest was 0.397 (1981) and the average was 0.236.

A limited ice fishery occurs off the mouth of Pikes Creek during February, March, and early April, depending on ice conditions. Steelhead are the main species sought. Harvest rates on adult steelhead destined for Pikes Creek were hard to derive because there was no way to separate untagged steelhead as true Pikes Creek spawners vs steelhead exhibiting shoreline movement prior to entering their own native stream. A $\underline{u}$ of 0.04 on Pikes Creek spawners for this ice and trolling fishery was a reasonably accurate estimate based on information received from harvested tagged steelhead (0.03 $\underline{u}$ for females and 0.01 $\underline{u}$ for males).

Whether the large 1981 harvest is indicative of things to come is unknown; however, water and weather conditions were excellent on the opening weekend, which pushed fishing pressure and harvest above normal.

The 1977-80 female in-stream $\underline{u}$ on Pikes Creek females averaged 0.196. The lake open water and ice fishing $\underline{u}$ was approximately 0.03, resulting in a total $\underline{u}$ of nearly 0.23. Male $\underline{u}$ was 0.19 in-stream, 0.01 in the lake, resulting in a total $\underline{u}$ of 0.20. The 1981 fishing mortality was not included due to its much higher rate compared to the previous four years.

TABLE 8. Estimate of number of spawnings by Pikes Creek steelhead, by age group.

Age	No. of Spawners 1st	2nd	3rd	4th	5th
			Females		
III	66	-	-	-	-
IV	284	68	-	-	-
V	127	83	48	-	-
VI	20	41	47	13	-
VII	-	4	11	9	4
VIII	-	2	-	2	1
			Males		
II	17	-	-	-	-
III	164	10	-	-	-
IV	45	22	6	-	-
V	18	24	16	3	-
VI	2	9	9	-	-
VII	-	-	2	1	3

TABLE 9. Annual fishing pressure and estimated in-stream steelhead harvest, 1977-81.

Year	No. Angler Trips	No. Harvested	Fish/Trip
1977	349	105	0.301
1978	320	186	0.581
1979	321	145	0.452
1980	327	213	0.651
1981	476	414	0.870

TABLE 10. Average harvest time, 1977-81.

Year	Hours/Steelhead
1977	12.0
1978	7.5
1979	7.1
1980	4.9
1981	5.4

TABLE 11. Annual in-stream fishing mortality rate, 1977-81.

Year	Mortality rate ($\underline{u}$)*
1977	0.120
1978	0.220
1979	0.162
1980	0.270
1981	0.397

*Average = 0.236.

The creel census indicated that approximately 6.9% of the successful anglers caught their limit of 5 steelhead, while 33.9% of the successful anglers caught 1 steelhead. It's interesting that anglers who harvested 1 steelhead accounted for 15.4% of the total catch, while those who caught 5 steelhead accounted for 15.8% of the catch. Table 12 shows a breakdown of harvest by successful anglers. Unsuccessful anglers constituted 37.9% of all fishermen.

POPULATION DYNAMICS

Spawner Model

Using spawner age structure, fishing mortality rate ($\underline{u}$), ratio of maiden to repeat spawners (%), and total mortality, the natural mortality rate ($\underline{v}$) for 1977-80 Pikes Creek female and male steelhead was determined. The fishery was considered a Ricker Type I fishery (Ricker 1975) (natural mortality occurs after fishing ends), therefore, $\underline{v}$ occurs after the fish leave the creek. For example, in a modeled female spawning population of 500 fish, age V spawning females constituted 156.1 of these, of which 49.4% were 1st-time spawners. (See Table 13). Fishing mortality (0.23) accounted for 35.9 fish of the 156.1, leaving 120.2 returning to the lake. The following year, 90.5 age VI female fish spawned, of which only 14.5 were 1st-time spawners, meaning 76 survived of the 120.2 age V that returned to the lake to spawn again. Spawning checks on scales indicated most fish spawn annually once mature. This means that 76 age V spawners out of 156.1 returned as age VI spawners, or 0.514 total mortality (80.2 fish) between age V and VI. Subtracting the 35.9 lost to fishing, leaves 44.2 to die of natural causes. The percentage of natural mortality is the portion lost after fishing mortality has been subtracted. The 44.2 fish that succumbed to natural causes is divided by 120.2 (total age V minus those lost to fishing), resulting in a 36.8% natural mortality.

The female community structure in Table 13 shows a lower natural mortality rate at age III than one would expect. Because of the small number of age III females in the spawning population, slight errors in $\underline{u}$ or age structure would result in the low estimated natural mortality. It is likely that $\underline{u}$ is lower and $\underline{v}$ higher in the actual spawning population. This error does not have a large impact on the outcome of the community structure.

The number of adult spawners in Pikes Creek averaged 989; 539 females and 450 males. Of these, 278 females and 325 males were 1st-time spawners.

Approximately 48.5% of the 1977-80 female spawning steelhead were repeat spawners and they averaged 23.5 inches in length. Looking at the actual average size of those field sampled, 23.0 inches is slightly below the modeled length. The cause of this error is unknown. The male cohort ($\underline{u}$ of 0.20) had only 27.8% of the spawners as repeats. In the model, they averaged 18.3 inches in length, while the average field measurement was 18.6 inches.

It is interesting to note that the Pikes Creek ratio of male to female spawner tag returns in subsequent years following tagging was 1:1.74, which is nearly identical to the scale analysis of 1:1.79 for repeat male spawners to repeat female spawners. These analyses were made independent of each other and strongly substantiate repeat spawner estimates.

WISCONSIN STEELHEAD SPAWNER POPULATION

As previously mentioned, Wisconsin's self-sustaining steelhead populations are confined to a small number of Lake Superior tributaries. With an estimated $\underline{u}$

TABLE 12. Harvest by successful anglers, 1977-81.

No. Steelhead Caught	Sample Size	% of Total Harvest	% of Successful Anglers
1	44	15.4%	33.9%
2	82	28.8%	31.5%
3	90	31.6%	23.1%
4	24	8.4%	4.6%
5	45	15.8%	6.9%

of 0.2 on the steelhead runs and creel information on the six major tributaries, a value of total stock size can be estimated at 38,000 spawners. Adding 2,000 spawners for the total run for smaller uncreeled watersheds, yields a total of approximately 40,000 steelhead spawning in Wisconsin tributaries to Lake Superior. Applying the Pikes Creek ratio of maiden/repeat spawners means approximately 24,000 are maiden spawners. Estimated number of eggs annually entering the watersheds is 73 million, with 55 million being deposited.

It is interesting that the number of angler steelhead trips (including those on Lake Superior) is 40,000, about equal to the number of spawning steelhead.

IMPACT OF CHANGES IN FISHING RATES

Knowing natural mortality rates (v) and percentage of repeat spawners, various u values were applied to the present spawning population to estimate changes in harvest, population size, average size, egg deposition, number of trophies (25 inches or greater), size of spawners, and number of maiden spawners.

The major assumption made when applying various u values to the Pikes Creek spawning population was that the 1977-80 u levels are considered stable harvest rates or an approximately equilibrium level. This means that at male u of 0.20 and female u of 0.23, the population will continue to maintain a constant population size, average size, egg deposition, and number of trophies. Local anglers and fishery personnel feel that Pikes Creek angler pressure has been constant over the past 10-15 years (post-lamprey years).

A measure of compensatory reaction of Pikes Creek steelhead or any Lake Superior steelhead population is unavailable. Therefore, in the following evaluation, compensatory reaction is not considered.

As the Pikes Creek study continues, insight into how low egg deposition can drop before recruitment is affected can be addressed. Eggs will be taken from Pikes Creek in the future for propagation, resulting in a decreased total egg deposition having a similar effect of raising u. Eggs will likely be taken for several years and resulting year classes (as spawners) will be monitored. The targeted egg take is 150,000 eggs annually, or 10% of the 1977-80 annual egg deposition rates.

TABLE 13. Female and male steelhead community structure for Pikes Creek, 1977-80.

Age	No. Spawners	Annual Fishing Mortality (avg. $\underline{u}$ = 0.23)	Annual Natural Mortality ($\underline{v}$)	Total Annual Mortality ($\underline{A}$)	Repeat Spawners	Maiden Spawners
			Female Steelhead*			
III	39.7	9.1	0.4 (1.3%)	23.9%	30.2	39.7
IV	156.5	36.0	41.5 (34.4%)	49.5%	79.0	126.3
V	156.1	35.9	44.2 (36.8%)	51.3%	76.0	77.1
VI	90.5	20.8	23.2 (33.3%)	48.6%	46.5	14.5
VII	46.5	10.7	26.1 (72.9%)	79.1%	9.7	0.0
VIII	9.7	2.2	6.5 (86.7%)	89.7%	1.0	0.0
IX	1.0	0.23	0.77 (100.0%)	100.0%	0	0
Total	500	114.9	142.7	-	242.4	257.6
			Male Steelhead**			
II	48	9.6	31.3 (81.5%)	85.2%	7.1	48.0
III	214.4	42.9	120.9 (70.5%)	76.4%	50.6	207.3
IV	132.8	26.6	57.3 (54.0%)	63.2%	48.9	82.2
V	69.7	13.9	34.3 (61.5%)	69.2%	21.5	20.8
VI	24.0	4.8	11.0 (57.1%)	65.8%	8.2	2.5
VII	8.2	1.6	6.1 (92.8%)	93.9%	0.5	0.0
VIII	0.5	0.1	0.4 (100.0%)	100.0%	0	0
Total	497.6	99.5	261.3	-	136.8	360.8

*23.5 inches - average size
1,759,990 - eggs entering creek
1,433,704 - eggs deposited
147.7 - number trophies

**18.3 inches - average size
8.7 - number of trophies

Males

During the study, the spawning male population consisted of 500 fish with a u of 0.20. Natural mortality (v) accounted for 261 fish (Table 13), while fishing mortality (u) accounted for 100 fish. Spawners averaged 18.3 inches with 137 as repeat spawners and 9 of trophy size. Reducing u to 0.0 would result in a male spawning population of 552 with an 18.6 inch average size, 190.5 repeat spawners, 16.7 trophies, and v accounting for all deaths (360.8). Maiden spawners would remain the same because of the previous steady egg deposition (1,433,704 eggs annually) for approximately two years. This will be referred to as the "interim period" (Table 14).

After 3 years with a u of 0.0, the increased egg deposition would begin to show up in age II mature males, and after 3 more years the increased egg deposition would show up as age II and III, etc. The determination of population size was based on 0.05% egg development to male spawner in 1977-80, assuming a 50:50 zygote sex ratio. Ensuing year classes of males would be completely affected in 8 years. The maiden spawners would be distributed in the male age structure as they were at the rate u of 0.2. If u remained constant at 0.0, it would take approximately 9 years to totally affect the present (1977-80) population level. This new level is referred to as the "second generation" (Table 15). At a u of 0.0, the second generation level of spawning males would total 1,014 with 31 trophies, 350 repeat spawners, and average size of 18.6 inches.

Another example would be if u was changed to 0.4 for male spawners. The interim population would consist of 453 spawners with 4 trophies, 181 harvested by fishing, and only 92 repeat spawners. The average size would drop to 17.9 inches. The second generation male population would total 305 with 62 repeat spawners and 243 maiden spawners. Fishing would harvest 122 while v would account for 121. The estimated effects of different u values on the present spawning males through an interim period to the second generation are depicted in Figures 7-11. The change in trophy males is not illustrated because of their low numbers at any u. In actual samples collected at the Red Dam, 6.9% of the males were of trophy size, slightly above the estimated 1.8% at a u of 0.2.

Realistically, u values of 0.3 and 0.4 are the levels some of our steelhead runs may face. Again, it is stressed that compensatory reaction is unaccounted for, and a u of 0.2 is the assumed equilibrium or near equilibrium level. At u of 0.3, the equilibrium male population would decline 5.2% at the interim level and 19.5% at 2nd generation (Fig. 7). At u of 0.4 the interim population would decline from equilibrium by 9.5% and the 2nd generation would decline by 38.9%.

It is interesting to note that because of the reduced size of the male population at u's of 0.3 and 0.4, the fish harvest is identical for each, 122 caught (Table 15). It is likely that at the interim level between a 2nd and 3rd generation (15-16 years), the harvest would be the same or less than that at the present equilibrium of u 0.2. As Figure 8 illustrates, the sport harvest would peak at a u of 0.4 (122) and drop at u's 0.5 and 0.6 as the 2nd generation is approached.

TABLE 14. Effects of various fishing mortality rates on steelhead spawning population in Pikes Creek, interim period.*

u	v	Fishing	No. Trophies	Population Estimate	Avg. Size (inches)	Repeat Spawners	Maiden Spawners	Egg Deposition
				Males				
0.0	360.8	--	16.7	551.7	18.6	190.5	360.8	--
0.1	308.4	52.4	12.2	523.1	18.5	162.3	360.8	--
0.2	261.3	99.5	8.7	497.6	18.3	136.8	360.8	--
0.3	218.4	142.4	6.0	474.4	18.1	113.6	360.8	--
0.4	179.5	181.3	4.0	453.2	17.9	92.4	360.8	--
0.5	143.7	217.1	2.5	434.0	17.7	73.2	360.8	--
0.6	110.8	250.0	1.5	416.7	17.6	55.9	360.8	--
				Females				
0.0	257.6	0.0	282.3	703.2	24.1	445.6	257.6	2,654,711
0.1	200.2	57.4	198.7	572.3	23.8	314.7	257.6	1,914,450
0.2	154.5	103.1	158.3	515.6	23.6	258.0	257.6	1,535,885
0.23	142.7	114.9	147.7	500.0	23.6	242.4	257.6	1,433,704
0.3	117.9	139.7	124.9	466.0	23.4	208.4	257.6	1,224,958
0.4	88.6	169.0	97.2	422.8	23.2	165.2	257.6	969,607
0.5	65.0	192.6	74.4	384.8	23.1	117.2	257.6	759,439
0.6	46.2	211.4	56.3	352.4	22.9	94.8	257.6	588,475

*Interim period begins at the point when fishing mortality significantly changes and ends at the point when this change totally influences the recruitment to the spawning population.

TABLE 15. Effects of various fishing mortality rates on steelhead spawning population in Pikes Creek, 2nd generation.

u	v	Fishing	No. Trophies	Population Estimate	Avg. Size (inches)	Repeat Spawners	Maiden Spawners	Egg Deposition
				Males				
0.0	663.7	0.0	30.8	1,013.9	18.6	350.2	663.6	
0.1	409.4	69.4	16.2	694.1	18.5	215.5	478.6	
0.2	261.3	99.5	8.7	497.6	18.3	136.8	360.8	
0.3	185.3	120.9	5.0	402.5	18.1	96.3	306.2	
0.4	120.5	121.9	2.7	305.5	17.9	62.2	242.4	
0.5	75.8	114.2	1.3	228.3	17.7	38.5	189.9	
0.6	45.2	101.9	0.6	169.7	17.6	22.6	147.1	
				Females				
0.0	477.8	0.0	457.7	1,182.5	24.1	704.7	477.8	4,405,450
0.1	267.9	76.6	265.5	765.4	23.8	420.8	344.6	2,572,399
0.2	165.7	110.6	169.8	553.1	23.6	276.7	276.4	1,667,046
0.23	142.7	114.9	147.7	500.0	23.5	242.4	257.6	1,433,704
0.3	100.8	119.7	106.8	398.8	23.4	178.3	220.5	1,067,171
0.4	59.8	114.7	65.7	286.3	23.2	111.8	174.5	675,348
0.5	34.6	102.2	39.6	204.4	23.0	67.7	136.7	419,134
0.6	19.0	86.9	23.2	144.8	22.9	38.9	105.9	254,712

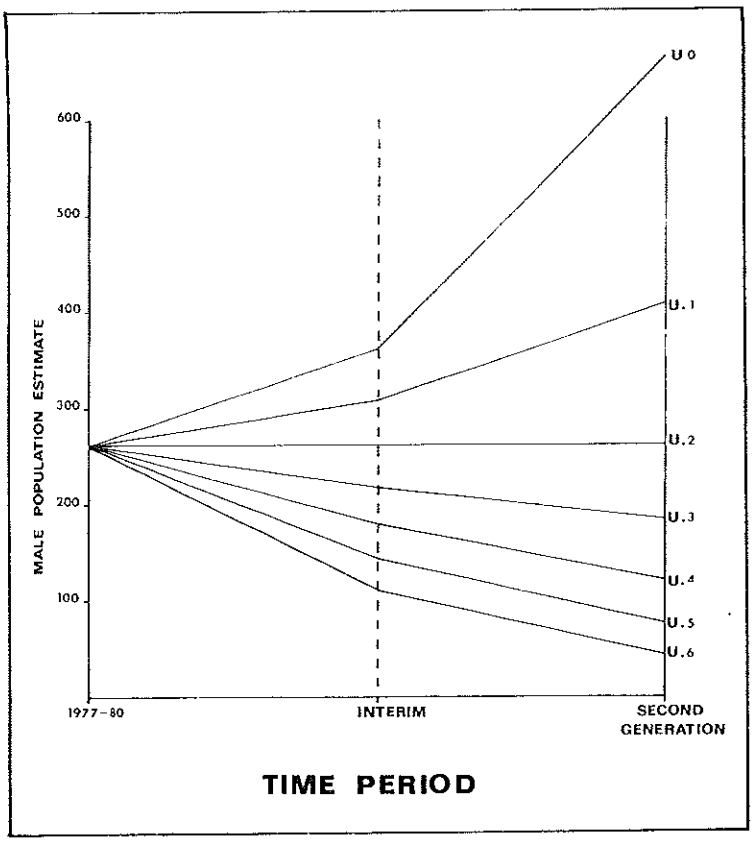


FIGURE 7. Number of spawning male steelhead entering Pikes Creek assuming various annual fishing mortality rates.

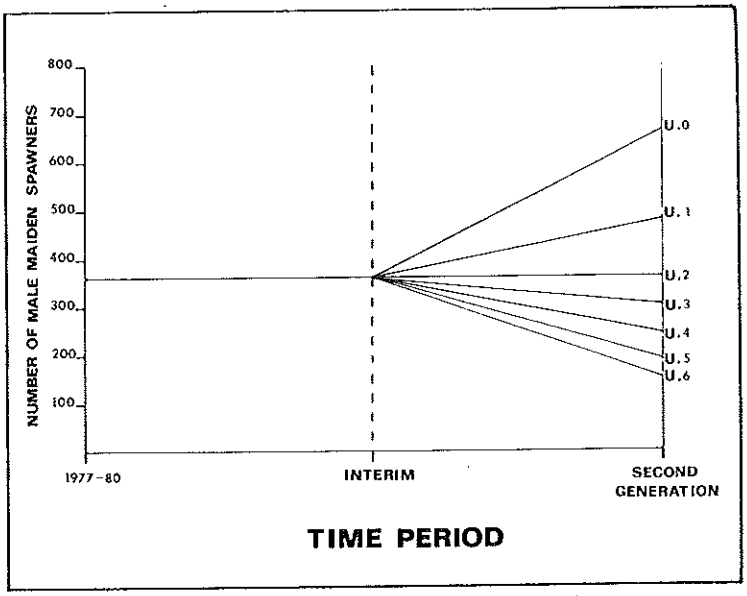


FIGURE 9. Number of maiden male steelhead entering Pikes Creek assuming various annual fishing mortality rates.

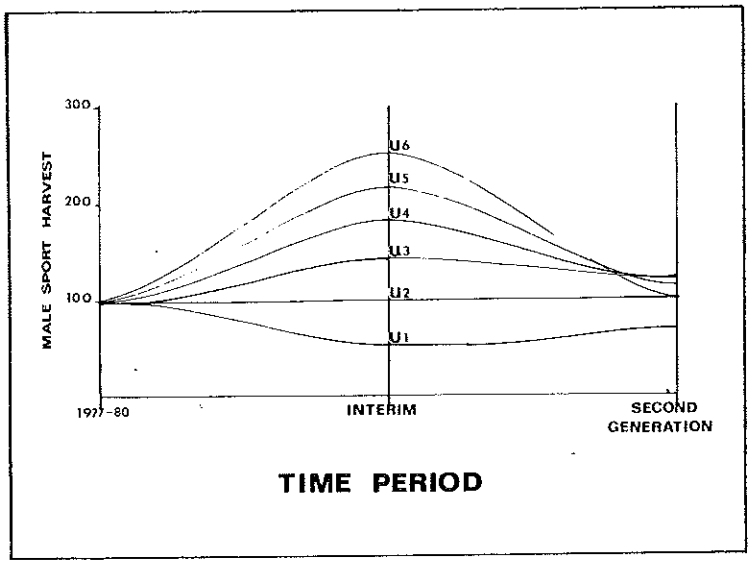


FIGURE 8. Sport harvest of Pikes Creek male steelhead assuming various annual fishing mortality rates.

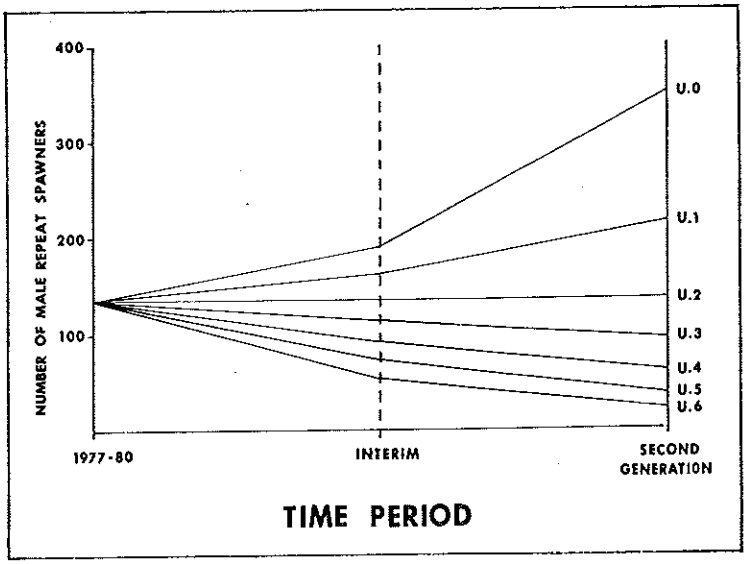


FIGURE 10. Number of male steelhead repeat spawners entering Pikes Creek assuming various annual fishing mortality rates.

Females

The same steps applied to the male spawners at various u values were used on the females. The only major difference in tabulating the changes was the factor used to estimate deposited egg survival to maiden spawners. For the earlier maturing males it was 0.05%, and for females the conversion was 0.036%.

Results of applying a range of fishing mortality rates from a u of 0.0 to a u of 6.0, to the equilibrium population level of 1977-80 ($\bar{u}$ = 0.23) are shown in Figures 12-18. As with males, u's of 0.3 and 0.4 are fishing mortality values that the female spawners could realistically face from an intensive fishery.

A u of 0.3 would decrease the equilibrium female spawning population by 6.8% during the interim period and 20.2% at the 2nd generation (Fig. 12). At a u of 0.4, the equilibrium female spawning population would decline 15.4% during the interim period and 42.7% at the 2nd generation level.

At a u of 0.3, estimated egg deposition would decline by 14.6% during the interim period and 25.6% at the 2nd generation (Fig. 14). At a u of 0.4, egg deposition would drop 32.4% during the interim period and 52.9% at the 2nd generation.

As expected, the female sport harvest (Fig. 15) would increase at u values higher than the equilibrium u of 0.23 during the interim period. By the 2nd generation, the sport harvest for u's of 0.4, 0.5, and 0.6 would be less than that at u of 0.23 (equilibrium level). The sport harvest of u 0.3 would be approaching that of a u of 0.23 by the 2nd generation.

Female trophy production at a u of 0.3 would drop 15.5% during the interim period and 27.7% during the 2nd generation (Fig. 13). At a u of 0.4, female trophy production would drop 34.2% during the interim and 55.5% at the 2nd generation.

As previously mentioned, compensatory reaction and stream carrying capacity were not taken into account in describing the dynamics of the Pikes Creek steelhead population. This means that the impact of changing u may have dampened the degree of change predicted. The number of maiden spawners was the least sensitive, followed by average size. The number of repeat spawners, population size, and trophies were the most sensitive to changes in u.

Another important factor concerning steelhead dynamics is the rearing capacity of the stream. For example, the estimated 1977-80 egg deposition of 1.43 million eggs may have exceeded the actual carrying capacity of the stream for the resulting YOY fish. When egg deposition exceeds stream carrying capacity, some increases in u will not reduce the number of maiden spawners. Conversely, a reduction in u will not increase maiden spawner production as predicted. We do not know the minimum egg deposition for Pikes Creek that would use the maximum carrying capacity.

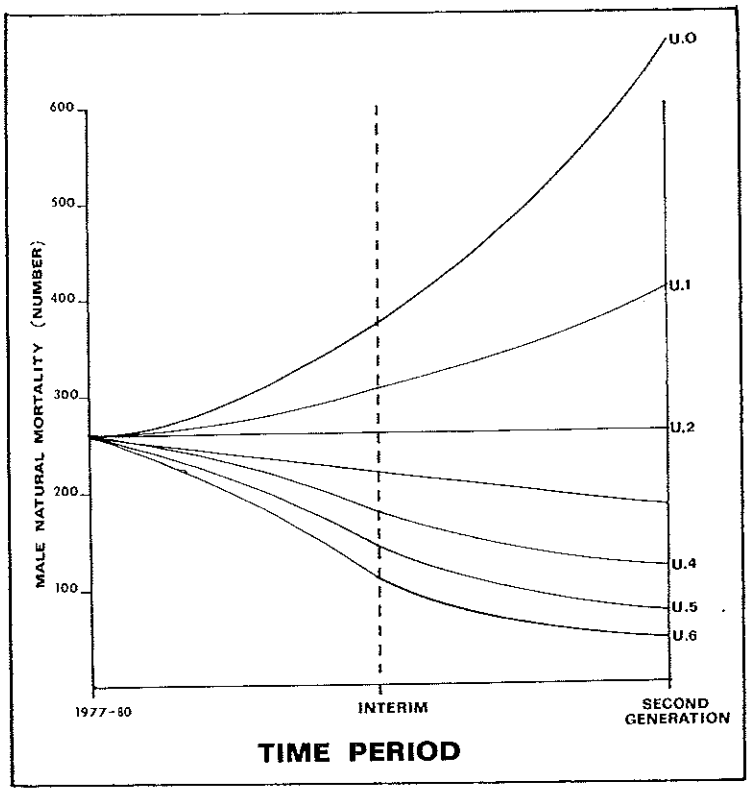


FIGURE 11. Natural mortality rates of Pikes Creek male steelhead assuming various annual fishing mortality rates.

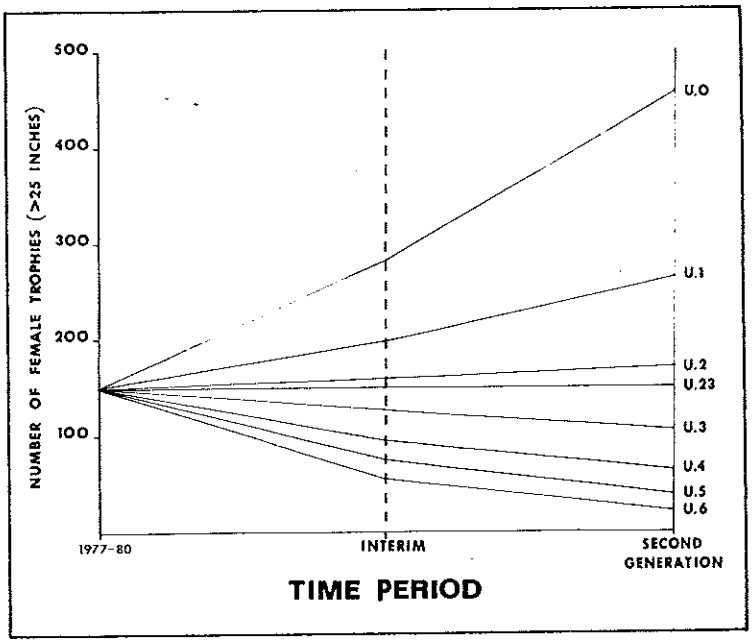


FIGURE 13. Number of trophy female steelhead (25 inches or greater) entering Pikes Creek assuming various annual fishing mortality rates.

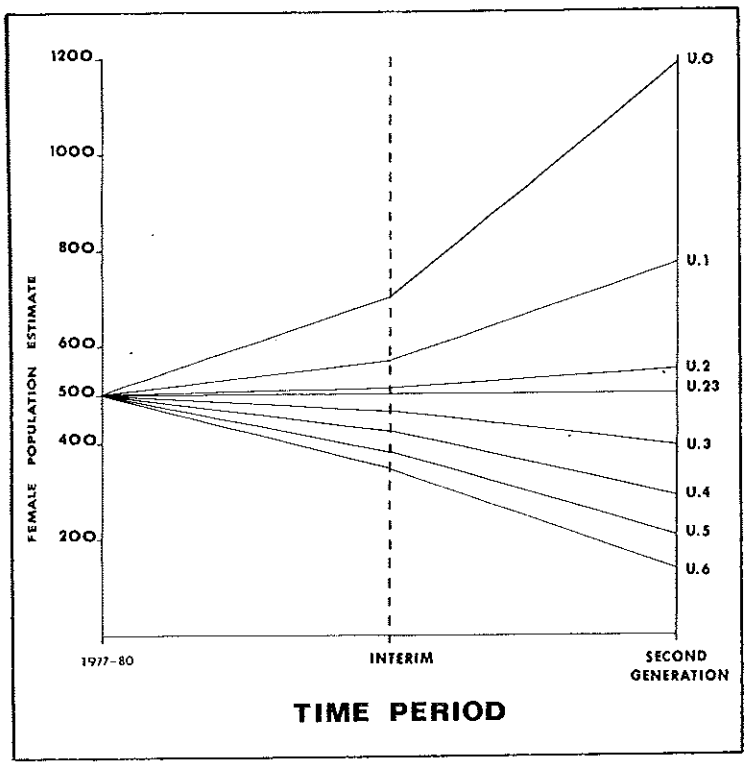


FIGURE 12. Number of spawning female steelhead entering Pikes Creek assuming various annual fishing mortality rates.

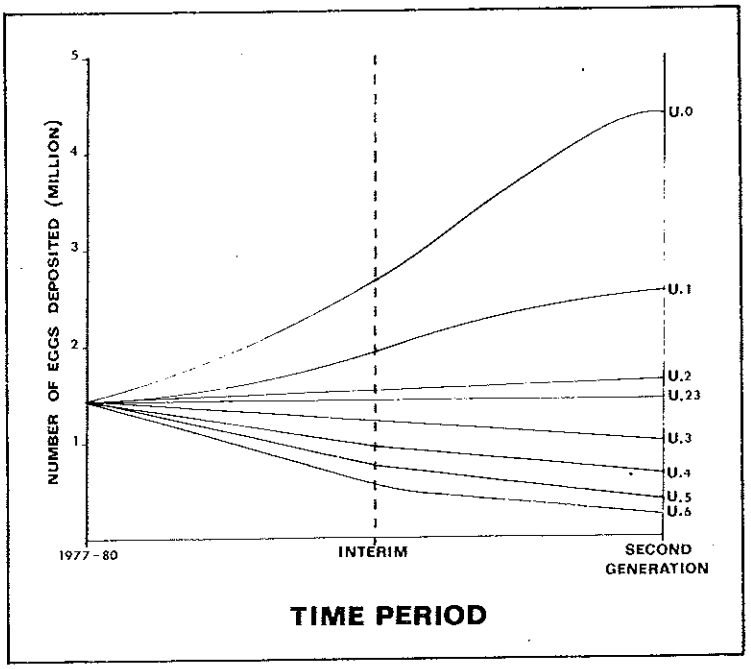


FIGURE 14. Steelhead egg deposition in Pikes Creek assuming various annual fishing mortality rates.

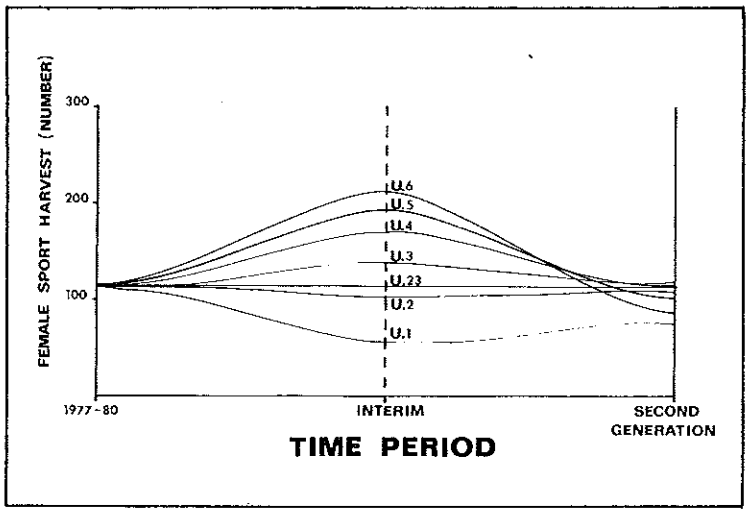


FIGURE 15. Sport harvest of Pikes Creek female steelhead assuming various annual fishing mortality rates.

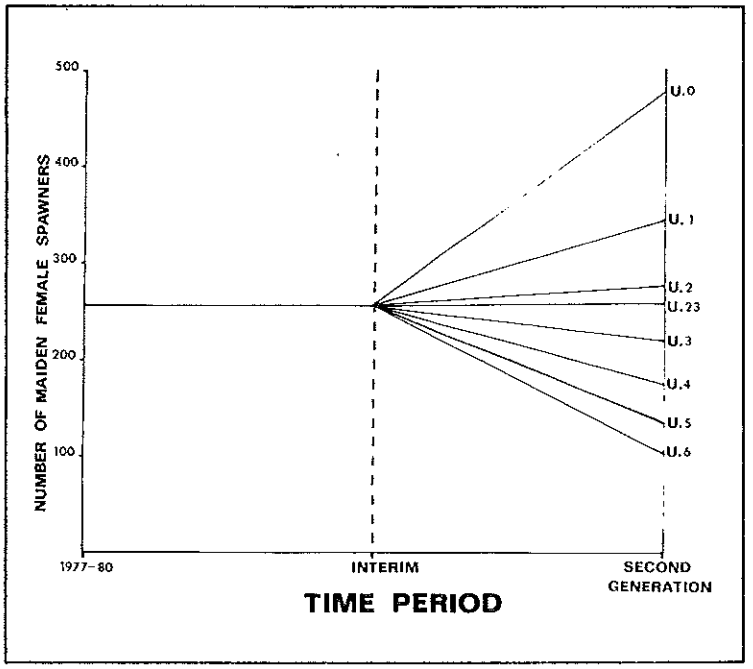


FIGURE 16. Number of maiden female steelhead entering Pikes Creek assuming various annual fishing mortality rates.

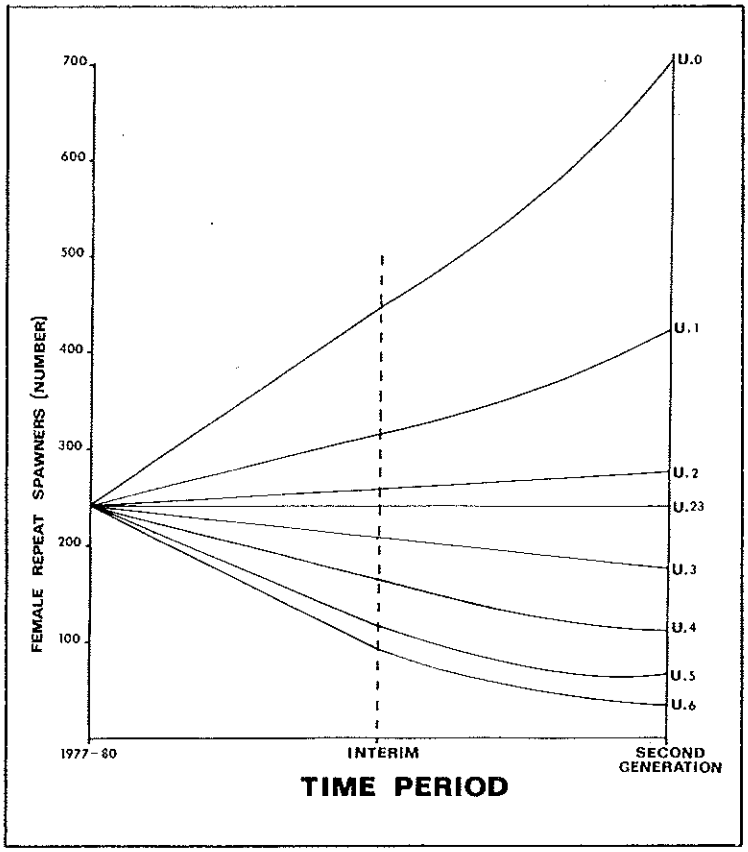


FIGURE 17. Number of female steelhead repeat spawners entering Pikes Creek assuming various annual fishing mortality rates.

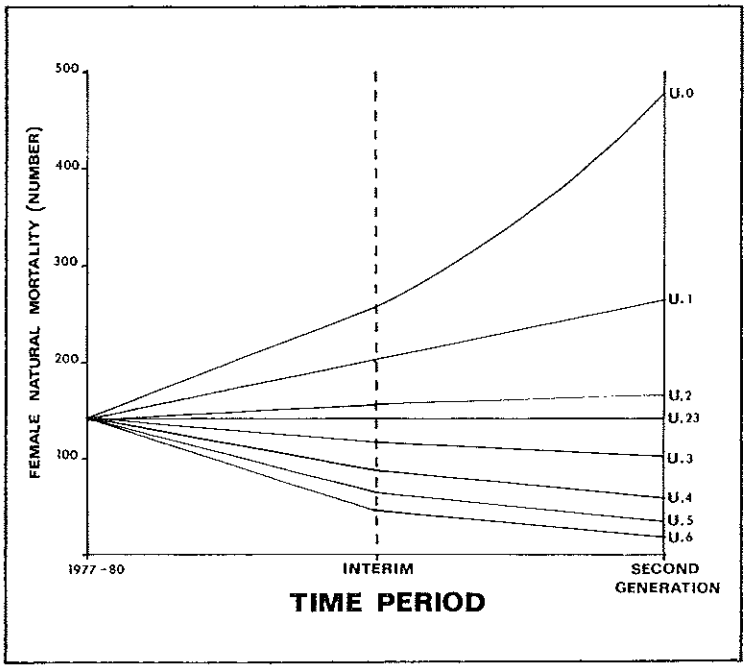


FIGURE 18. Pikes Creek female steelhead natural mortality rates assuming various annual fishing mortality rates.

MANAGEMENT CONSIDERATIONS

Present Steelhead Management On Lake Superior Tributaries

Presently, Wisconsin's steelhead season is comprised of a regular season, and special early and late seasons on selected streams (Append. A). The special early season--opening the Saturday nearest 1 April--applies primarily to medium flow (approximately 20 cfs) size streams. The extended fall season is an attempt to harvest spawning salmon and applies to all streams with fall salmon runs. Both early and late trout seasons have a 10-inch minimum size limit.

The regular trout season opens on the first Saturday in May and closes 30 September, with a 6-inch minimum size limit. The bag limit for all seasons is 5 trout or salmon in aggregate. All of Pikes Creek is open for the regular season and from Lake Superior to the Red Dam during the extended fall season. As of 1982, the Brule River is open all year from U.S. Highway 2 to the mouth of the river at Lake Superior, while the remainder of the Brule is open only during the regular season.

In Minnesota, the trout and salmon season for Lake Superior tributaries (other than the St. Louis River) runs from 17 April through 30 September, with a 10-inch minimum size limit. The bag limit is 5 fish, of which only 3 may be 16 inches or longer. In Michigan, the trout and salmon season is similar to Wisconsin's, with a limit of 5 fish and minimum size limit of 10 inches. Michigan's season runs from 30 April through 30 September. All states allow steelhead to be taken from Lake Superior year-round. No commercial harvest is allowed by state-licensed anglers, but tribal fisheries do allow the harvest of steelhead, particularly by home-use anglers using gill nets in the lake. The tribal harvest of Pikes Creek steelhead in Lake Superior is unknown, but is considered marginal.

Regulatory Options

Using the dynamics of the Pikes Creek steelhead population, regulatory options can be evaluated using biological results and anticipated reaction of anglers to a regulation.

Following are nine regulatory options to managing the Pikes Creek and similar steelhead populations.

(1) Unchanged regulations

Biological result: At present u, the population will remain healthy and stable. If pressure and efficiency increase, egg deposition and number of trophy size fish will decline proportionately.

Social result: Status quo. Some question as to ethics of bag limit of 5. If pressure increases, crowding will reduce quality of fishery.

(2) Change in daily bag limit

A. 4 fish — Reduce $\underline{u}$ by 0.01 for each sex (0.23 to 0.22). Egg deposition increases by 51,091 (3.6%). Trophies increase by 5.3 fish (3.6%).

B. 3 fish — Reduce $\underline{u}$ by 0.02 for each sex (0.23 to 0.21). Egg deposition increases by 102,182 (7.1%). Trophies increase by 10.5 fish (7.1%).

C. 2 fish — Reduce $\underline{u}$ by 0.056 for each sex (0.23 to 0.174). Egg deposition increases 211,545 (14.8%). Trophies increase by 21.9 fish (14.8%).

D. 1 fish — Reduce $\underline{u}$ by 0.125 for each sex (0.23 to 0.105) Egg deposition increases by 446,296 (31.1%). Trophies increase by 45.9 fish (31.1%).

NOTE: Number of trophy males so low that estimation of reduced bag limits not warranted.

Biological result: As $\underline{u}$ is reduced, the number of trophies and egg deposition increases up to 31.1% at a bag limit of 1. At bag limits of 2 and 3, the number of trophy fish and egg deposition increases 14.8% and 7.1%, respectively.

Social result: As the bag becomes more restrictive, the fishing pressure may stabilize and/or subside. Likely negative public reaction to a bag limit of 1. Likely support for reduction to 2 or 3.

In some of the larger anadromous streams, a lower bag for either the early or regular season could be applied; for example, a 2-fish bag during the early season and the 5-fish bag for the regular season. Prior to 1975, the bag limit during the special early and late seasons was 5 fish, of which only 2 could be steelhead or salmon. This reduced the harvest on pre-spawning steelhead females, allowing for greater egg deposition and more trophies. In the medium flow, anadromous streams (Cranberry, Flag, and Sioux rivers, and Fish Creek), 58.3% of the spring fishing pressure occurred during the early season (April), while 41.7% occurred during the regular spring season (May to mid-June). On the Brule River (1978-79), approximately 79.5% of the spring pressure occurred during the early season (April) and 95% of the spring steelhead harvest vs. May-June. Obviously, a lower bag limit in the early season would reduce the $\underline{u}$. It also may spread some pressure to the regular season. This 2-fish bag limit during the special season would have no impact on smaller streams such as Pikes Creek, which opens with the regular season. This proposal passed the Wisconsin Conservation Congress in 1983 and became law in 1984.

(3) Limit on number of females in bag limit

A. 4 females — Reduce female harvest by approximately 1%. It is rare that all 5 in the bag are females so a change to only 4 females is not significant.

B. 3 females — Reduce female harvest by 3-4%.

C. 2 females — Reduce female harvest by 10-11%.

D. 1 female — Reduce female harvest by 39-40%.

Biological result: With males constituting approximately 50% of run, an increased $\underline{u}$ for males may interfere with spawning behavior and may possibly lower egg fertilization rate.

Social result: This may be difficult to enforce due to an exchange of fish between anglers.

(4) Season change

Obviously a shortened season would reduce $\underline{u}$ and allow for more escapement to spawn. If $\underline{u}$ is threatening the size and quality of the steelhead run, reduction of season length would be contrary to the accepted philosophy of allowing more time for the public to use their resource. Over the past years, numerous changes expanding the anadromous steelhead season have been incorporated into the regulations. A shortened season would likely not be socially acceptable because it would reduce availability to the resource and cause increased crowding during the season, thereby diminishing the quality of the fishing experience.

(5) Closed areas

Portions of the streams presently open could be closed to allow some added escapement. This has been done during the early season in the upper portions of the Brule, Sioux, Cranberry, and Flag rivers, and Fish Creek. Additional closed areas would crowd anglers into the open areas, reducing the quality of the experience.

(6) Limited entry

This is a possible management practice for the distant future. Presently limiting entry is not necessary or financially feasible to administrate.

(7) Stocking

Steelhead stocking to date has proven unsuccessful in providing spawners to sport anglers. The importance of self-sustaining steelhead stocks in Wisconsin waters of Lake Superior became evident in the 1970's when attempts to stock steelhead in anticipation of adult returns to our streams definitely failed. Stocked steelhead exhibited low survival and extensive wandering (Wis. Dep. Nat. Resour. files).

(8) Gear

A restriction on lure types or hook size and configuration might reduce intentional snagging, thereby lowering $\underline{u}$. Whether this is a practical and enforceable measure is doubtful.

(9) Habitat improvement

Experiments could be designed to increase smolt production from the streams. Kwain (1981) suggests that older smolts have a higher percentage return as adults, so production may be directed to hold smolts in streams longer. In contrast, if the nursery is limited, stream manipulation to produce earlier descendants may be more economical. The earlier smolts would have a higher mortality rate, but the nursery could produce many more juveniles to compensate for the loss.

Until stream habitat manipulation is a proven, economical management tool, habitat protection should receive our primary attention.

MANAGEMENT RECOMMENDATIONS

Two types of anglers fish for steelhead: one who enjoys catching fish and taking them home, and another who enjoys catching trophy size steelhead and puts less importance on bringing home as many fish as possible. Management goals must address both of these recreational philosophies. A spawner population with a $\underline{u}$ of 0.2 to 0.3 is a desirable size structure; a $\underline{u}$ of 0.2 seems preferable because it has a 28% lower harvest rate, yet 22% more trophies in the run.

Whatever level of exploitation is chosen, monitoring the various steelhead populations to estimate $\underline{u}$ levels is costly and impractical. A relatively inexpensive monitoring system can be accomplished by obtaining scale samples to determine the ratio of maiden to repeat female spawners. A 1:1 ratio (50% of the females are repeat spawners) is comparable to a population with a $\underline{u}$ of 0.2 (Table 14). If 45% of the females are repeat spawners, the $\underline{u}$ would be 0.3. Male spawners contribute little to the trophy portion of the Pikes Creek steelhead population (6%), so monitoring emphasis should be placed on the females.

This relationship of $\underline{u}$ and percent of repeat spawners found in Pikes Creek may not be strictly applicable to other Lake Superior steelhead populations; however, the technique can be used to determine other populations' specific female spawner composition.

If a specific steelhead population is experiencing an increase in $\underline{u}$ beyond the desired levels, numerous control measures can be taken. A reduction in the bag limit is preferable. For Wisconsin streams, if a bag reduction is necessary, a limit of 2 during the regular season is reasonable. A bag of 3, of which only 1 can be female, is another viable alternative. If only one female is allowed in the daily bag, the female harvest can be reduced theoretically by 39-40%. Realistically, swapping of fish between anglers to maximize their daily catch would reduce the impact of the 1 female limit, or reduce overall female harvest by possibly 30%.

LITERATURE CITED

Devore, Philip W. and John G. Eaton
1983. An investigation of spinal deformity of trout (Salmo sp.) in the Brule River, Wisconsin. J. Great Lakes Res. 9, No. 1, pp. 69-73.

Hassinger, R. L., J. G. Hale, and D. E. Woods
1974. Steelhead of the Minnesota North Shore. Minn. Dep. Nat. Resour. Tech. Bull. 11, St. Paul.

Johannes, S. I., L. M. Sather, and C. W. Threinen
1970. Surface water resources of Bayfield County. Wis. Dep. Nat. Resour. Madison. 372 pp.

Kwain, W.
1971. Life history of rainbow trout (Salmo gairdneri) in Batchawana Bay, eastern Lake Superior. J. Fish. Res. Board Canada 28:771-75.

1981. Population dynamics and exploitation of rainbow trout in Stokely Creek, eastern Lake Superior. Trans. Am. Fish. Soc. 110:210-15.

MacKay, H. H.
1963. Rainbow trout. pp. 91-101 in Fishes of Ontario. Ont. Dep. Lands and For., Toronto.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Resour. Board Canada 191. 382 pp.

ACKNOWLEDGMENTS

This study was made possible through the assistance of Patrick Aschenbauer, Dennis Pratt, Scott Hulse, and Mary Halvorson. Charles Kreuger (Cornell University), Wen-Hwa Kwain (Ontario Ministry of Natural Resources), and Lawrence Claggett (Wisconsin Department of Natural Resources) reviewed the manuscript.

Production Credits

Charmaine Daniels and Donna Mears, Editors
Donna Mears, Copy Editor
Jan Baxter, Julie McCutchin, Word Processors